Optical Variability and Bottom Classification in Turbid Waters: Phase II

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LONG-TERM GOALS

The development of an optical methodology, valid for Case II coastal waters, for the remote classification of the sea bottom including sediment type (calcareous/quartz sand, clay, mud), benthic flora (benthic diatom and algal mats, seagrasses, green and red macrophytes), and bottom structure (reef, rock). The methodology will exploit elastic and inelastic spectral information as well as 3-dimensional size, shape, and texture information determined by optical methods.

OBJECTIVES

The deconvolution of the components of the underwater and water-leaving light fields in coastal waters. The determination of feature vectors, including 3-D morphology, which hold information unique to different bottom types and structure for use in an automatic classification strategy. The significant challenge inherent in this work is the need to identify and address all significant factors affecting the underwater light field.

APPROACH

This project utilizes the Bottom Classification/Albedo Package (BCAP), a suite of optical instrumentation developed under previous ONR funding, to acquire the hyperspectral database required to deconvolve the components of the underwater and water-leaving light fields (Carder et al., 1998; Costello et al., 1997; English et al., 1998; Hou et al., 1998a; Patch et al., 1998). *In situ* instrumentation includes a 512-channel upwelling radiometer, a 512-channel downwelling irradiometer, two 6-channel, intensified bottom cameras, a single-channel, intensified bottom camera, a dual-laser, optical altimeter/chlorophyll probe, COTS instrumentation to measure attenuation, absorption, backscattering, and fluorescence at various wavelengths, and a real-time microtopography assembly. Two BCAP systems have been configured for deployment on both our ROSEBUD remotely operated vehicle (ROV) and our Ocean Voyager II (OV-II) autonomous underwater vehicle (AUV).

A three-dimensional microtopography sensor package, the Real-time Ocean Bottom Optical Topographer (ROBOT) has also been developed for this project. ROBOT is a bi-static, laser-line

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imaging system where deviation of the projected line from the position in the image it would occupy at mean altitude is proportional to the relief of the bottom/object. ROBOT has been designed as a payload module for deployment aboard the Ocean Explorer (OEX) class AUV developed by Florida Atlantic University. Accurate range data to various bottom components is required for albedo correction for path attenuation, and 3-D shape assists in bottom and object classification, especially for turbid waters.

WORK COMPLETED

- Fluorescence imagery of the bottom, including natural and man-made objects, has been secured at several sites using an intensified video camera and a narrow-band-pass (NBP) filter centered at 685 nm from both our ROV and the Ocean Voyager II AUV.

- A ROBOT prototype (utilizing the bi-static, laser-line imaging approach for micro-topography) has been successfully tested in situ acquiring 3-D data for corals, sand waves and man-made, mine-like objects using our ROV platform. The system utilized the BCAP intensified video camera and a NBP filter used for fluorescence imagery in conjunction with a 685 nm, 20 mW diode laser equipped with line generator optics. Since the prototype was a video-based system, it was not capable of real-time acquisition and display of bathymetry. The results, however, showed that the technique was appropriate for ocean bottom applications.

- The ROBOT module has been constructed, exercised in the laboratory, and deployed at sea (Lee Stocking Island, Bahamas) aboard the OEX AUV. The machine vision sensor is capable of acquisition of up to 700 scan lines per second. It has been housed along with a Pentium-CPU, single board computer and mass storage in a pressure housing. Ethernet data output rates allow real-time data display. The light source for the system is a 532 nm, 65 mW, frequency-doubled, diode-pumped laser fitted with a non-gaussian line generator and housed for underwater deployment. In order to accommodate different operational scenarios, the laser source is coupled to the microtopography system with an adjustable bi-static separation from the camera (nominally 1 m) and an adjustable viewing angle. Height discrimination of 1 cm was achieved over sand ripples.

- Outfitting and enhancing our 34-foot LOA underwater-vehicle-support vessel, the R/V Subchaser, continues. The Subchaser was utilized near Marathon Key, Florida Keys for seven days in June 1997 deploying the ROSEBUD ROV and the Ocean Voyager II AUV. In September 1997, the Ocean Voyager II AUV was transitioned to USF and deployed successfully in Tampa Bay. The Subchaser has also been utilized for deployment of underwater vehicles in an acoustic study off Indian Rocks Beach, Fl and made the trip to Lee Stocking Island, Bahamas to participate in the 1998 CoBOP field campaign (May 15 to June 2, 1998). In October, the Subchaser was used ascalibraton.validation support for the An-2 aircraft (NRL-Washington) flying the PHILLS sensor on the west Florida coast.

- A transom-mounted video camera (Sony XC-777) for bottom imaging has been integrated with DGPS positioning. An upgrade from a ORE Trackpoint LXT acoustic tracking unit to an ORE Trackpoint II system operating as part of a DGPS-based Integrated Positioning System on the R/V Subchaser has been accomplished (Peacock et al., 1998).

- All mechanical and electronic systems aboard the ROSEBUD ROV have been overhauled/upgraded and a new, hydrodynamically efficient “crash cage” has been designed, constructed, and installed which integrates a recovery rail similar to those used for AUV launch/retrieval. This system allows

operations in more adverse weather conditions than does traditional methods (ship's cable and tag lines).

- The Ocean Voyager II AUV host computer hardware and LONWorks operating system software have been upgraded to Ocean Explorer class standards by Florida Atlantic University. In addition, the vehicle has been formally transitioned to USF by FAU for use by our group. Vehicle engineering support is provided by USF's Center for Ocean Technology.

- A u-frame extension for the deployment/retrieval of underwater vehicles on the R/V Subchaser has been designed, constructed and utilized. Both the OV-II AUV and the OEX Magellan AUV (with various payload modules) as well as the ROSEBUD ROV and various "drop packages" have been deployed off the Subchaser.

- A Doppler Velocity Log (DVL) unit, ORE Navigator, has been integrated into the OV-II AUV. The DVL provides acoustic 3-dimensional "bottom lock", significantly enhancing precision-positioning capabilities.

RESULTS

Due to the high attenuation of 685 nm radiation by water, essentially no solar radiation at that wavelength is reflected from below a few meters of depth (Costello et al., 1998a). However, the attenuation of the blue-green radiation band that pumps chlorophyll fluorescence at that wavelength is lower by about a factor of twenty (Costello et al., 1998b). This has been exploited to produce high-contrast, NBP imagery of non-fluorescing objects silhouetted against the natural, solar stimulated (fluorescing) background (Fig.1) for depths from 6 – 25m. The ability to acquire NBP imagery is, however, a function of the water IOPs within the pass band. During an ROV deployment below 30m off Sombrero Key, for example, fluorescence from benthic diatoms was inadequate for the exploitation of this imaging method. However, in 25 m water depth in the Dry Tortugas and the Bahamas, there was bottom fluorescence sufficient to acquire imagery in the 685 nm band and even in a band centered at 730 nm. The parameterization of the method considering different bottom types and the spectral irradiance available at depth is underway.

A bi-static, laser-line-imaging system (ROBOT) has provided micro-topography of the bottom and of bottom objects with 1 cm resolution in three dimensions. The targets imaged ranged from sand waves with a few centimeters relief to stromatolites (Adderly Channel, Bahamas) with more than one-meter relief.

IMPACT/APPLICATIONS

Solar-stimulated fluorescence imagery of the bottom can be acquired in any area where the depth is sufficient to effectively quench 685 nm reflected solar radiation and where blue-green radiation penetrates sufficiently to stimulate 685 nm fluorescence to a level which allows image formation by the sensor. A parameterization of the effective operational environmental variables including IOPs, AOPs, and bottom characteristics is underway (Hou et al., 1997, 1998b; Ivey et al., 1998; Lee et al., 1996a, 1996b, 1998a, 1998b, 1998c, 1998d, 1998e). The significance is two-fold: first, since the bottom is the source, the imagery acquired is free from the backscattered path radiance generally associated with contrast degradation in underwater imagery (Pratt et al,. 1997); second, animals and man-made objects do not, generally, fluoresce at 685 nm. Given the appropriate environmental

parameters, this makes possible the visualization of bottom objects which may not be apparent using either active or passive reflection (elastic) imaging techniques. Applicability ranges from assessment of the standing stock of sponges to underwater mine detection.

Real-time, high-resolution micro-topography also has diverse potential applications. The most obvious of these is to provide the range information required to correctly interpret actively or passively stimulated fluorescence imagery. Other applications include coral biomass quantification, sandwave analysis, and bottom type/structure/object classification. Real-time 3-D imaging will be achieved from AUV-deployed systems via RF-ethernet transmission via a surface-towed float or by direct, underwater, optical communication.

TRANSITIONS

A number of instrument systems and deployment platforms developed under this funding have transitioned from prototype engineering mode to operational scientific mode.

1. The Ocean Voyager II AUV has been upgraded to OEX class and formally transitioned from Florida Atlantic University to the University of South Florida.
2. The R/V Subchaser is now routinely utilized for the deployment of underwater vehicles. Co-operative work has been performed with several ONR-funded efforts as well as with work funded through NRL-Stennis, NRL-Washington, and NASA.
3. The ROSEBUD ROV has transitioned from a test-bed platform to a working platform. During the 1998 CoBOP field campaign, for example, the vehicle was used to acquire 490 hyperspectral irradiance/radiance profilesand high-spectral elastic and inelastic bottom imagery.
4. Several payload modules for the Ocean Explorer fleet of AUVs have been deployed and are approaching the stage where they will be available to support field operations. These include ROBOT (described here) and three other payloads developed at USF: SIPPER and DLS (marine particle enumeration systems) and SEAS (a micronutrient and spectrophotometric pH sensor).

RELATED PROJECTS

This project benefits from an association with the ONR project Coastal Benthic Optical Properties (CoBOP) and with Florida Atlantic University Ocean Engineering program. CoBOP field exercises allow the opportunity to deploy hardware systems developed under this funding to image bottom structure/objects while benefiting from significant ancillary data from other CoBOP investigators.

Similar symbioses exist with the ONR Bottom Boundary Layer project, the ONR HyCODE project, and with the multi-agency ECOHAB effort which have targeted the west Florida shelf as a study site. Our co-operative participation enhances these projects and makes complementary data available to us for our work.

Efforts within our group toward model inversion (funded through ONR/CoBOP and NASA) utilizing remote sensing reflectance provides bathymetry and water optical properties.

Co-operative relationships are also foreseen with several other projects associated with the AUV and AUV sensor development program between USF and Florida Atlantic University. Our upcoming

participation (utilizing ROBOT) in Navy-sponsored mine detection exercises off Ft. Lauderdale in early December 1998 is just one example.

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